PASSIVE SOLAR RETROFIT FOR HEATING OF STAKNA POWER HOUSE

FINAL REPORT

ASHOK GADGIL
SANJAY RASTOGI

TATA ENERGY RESEARCH INSTITUTE
NEW DELHI

MAY 1988

The first progress report of this project was delivered to the Govt. of J & K in September 1987. It is reproduced in Appendix A.

Subsequent to delivery of this first progress report, research scientists of TERI visited Stakna and Srinagar and met with several important officers of PDD, concerned with civil and electrical construction and operations. To incorporate the detailed discussions with these officers, TERI has made several significant changes to the retrofit measures recommended in the first progress report. These alterations take into account the structural and operational requirement at the Stakna Power house.

The modified recommendations of passive solar heating of the Stakna Power house are presented in Appendix B.

Based on the structural and operational requirements at Stakna Powerhouse, TERI undertook a series of detailed computer simulations of the hourly thermal performance of the Stakna Powerhouse. The performance predicted after retrofitting (based on the recommendations of Appendix B) is shown in Table 1. The predicted hourly indoor temperatures for the first day for the months of March, June, September and December is shown along with the observed outdoor hourly temperatures in Figs. 1-4. It is seen that the indoor

temperatures can be kept comfortably above freezing even in the severe winter night-time. Indoor temperatures are likely to reach uncomfortable levels during the summer unless provisions are made for increasing the ventilation rate by artificial means; however this is only of secondary concern.

The performance predicted in the following pages assumes good quality of materials and workmanship in the retrofit of the Stakna Powerhouse. TERI will be happy to assist the Govt of J & K by providing detailed technical guidance for ensuring the quality of the materials and the workmanship used for retrofitting the powerhouse as per terms approved for this project.

TABLE 1

ANNUAL TIME VS. TEMPERATURE PERFORMANCE PREDICTED FOR STAKNA POWERHOUSE AFTER RETROFITS

HEATING SEASON COMFORT CHART
TEMPERATURE VS. HOUR OF DAY

HOUR	TEMP(°F) 22	26	30	34	38	42	46	50	54	58	62	66	70	74	78	82	86	90	
1	1	0	0	0	0	0	1	8	31	41	47	59	48	42	48	25	11	3	
2	1	0	0	0	0	0	4	13	40	43	50	49	50	42	42	22	7	2	
3	1	0	0	0	0	0	7	27	39	42	50	48	51	36	40	20	4	0	
4	1	0	0	0	0	1	14	40	33	48	43	46	48	37	40	12	2	0	
5	1	0	0	0	0	7	23	39	34	44	44	51	38	40	34	10	0	0	
6	1	0	0	0	0	10	36	34	36	42	43	51	34	43	25	10	0	0	
7	1	0	0	0	2	18	37	33	33	42	40	51	32	43	29	4	0	0	
8	1	0	0	0	5	23	36	30	30	43	39	51	33	43	27	4	0	0	
9	0	1	0	0	4	22	32	32	34	41	36	51	30	47	27	8	0	0	
10	0	1	0	0	0	12	34	37	32	34	36	55	36	38	36	14	0	0	
11	0	0	1	0	0	2	29	32	33	34	39	41	54	37	38	23	2	0	
12	0	0	0	1	0	0	7	34	31	36	37	42	47	51	36	33	10	0	
13	0	0	0	0	1	0	0	10	43	25	39	44	42	51	50	38	18	4	
14	0	0	0	0	0	1	0	3	18	38	30	48	44	45	52	40	31	15	
15	0	0	0	0	0	0	1	1	3	33	35	35	53	44	51	54	31	24	
16	0	0	0	0	0	0	0	2	1	11	46	29	59	46	45	60	34	32	
17	0	0	0	0	0	0	0	3	0	4	45	32	59	43	51	54	37	37	
18	0	0	0	0	0	0	0	2	1	4	40	37	57	45	56	50	37	36	
19	0	0	0	0	0	0	0	2	1	6	41	38	58	50	54	48	37	30	
20	0	0	0	0	0	0	0	2	1	10	46	40	51	60	51	43	38	23	
21	0	0	0	0	0	0	0	2	1	18	46	50	51	58	48	44	28	19	
22	0	0	0	0	0	0	0	2	6	29	47	44	56	60	39	46	23	13	
23	0	0	0	0	0	0	0	4	9	39	46	45	61	52	38	44	18	9	
24	0	0	0	0	0	0	0	5	15	46	48	52	55	46	39	39	15	5	
TOTAL	8	2	1	1	12	96	261	397	505	753	1013	1089	1147	1099	996	745	383	252	8760

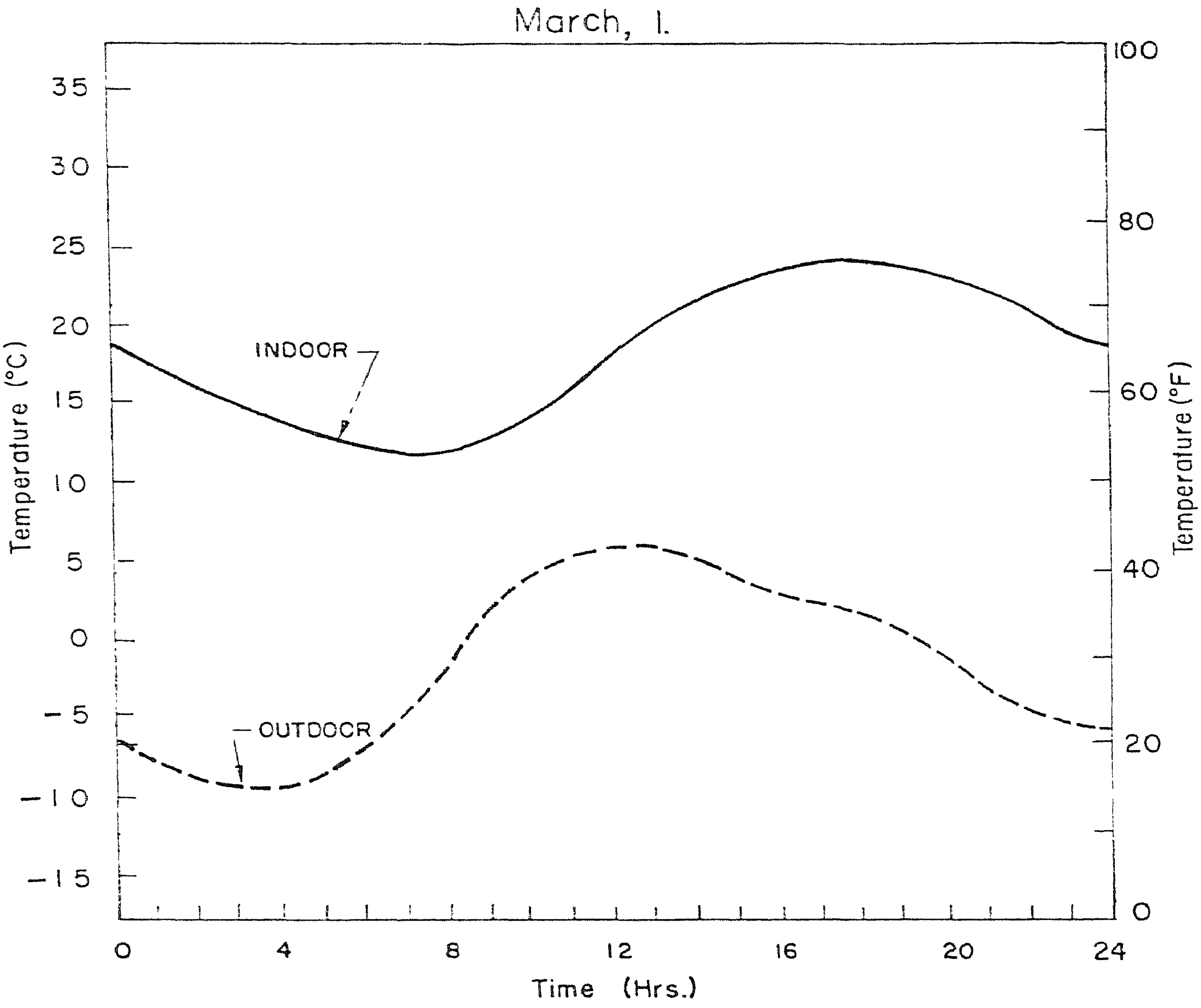

March, 1.
Temperature (°C)
35
30
25
20
15
10
5
0
-5
-10
-15
Temperature (°F)
100
80
60
40
20
0
INDOOR
OUTDOOR
0
4
8
12
16
20
24
Time (Hrs.)

Fig. 1

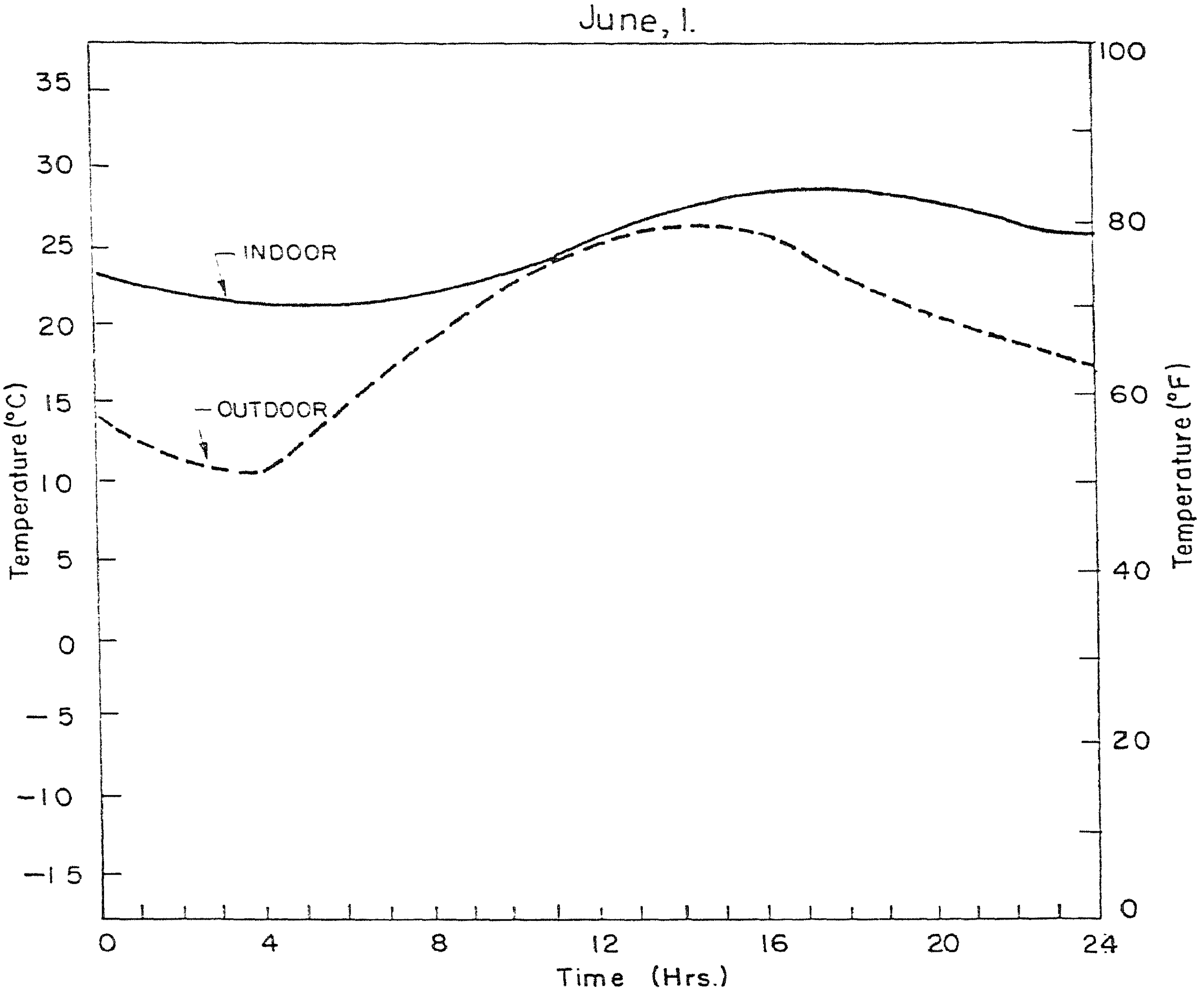

June, 1.
INDOOR
OUTDOOR
Temperature (°C)
35
30
25
20
15
10
5
0
−5
−10
−15
Temperature (°F)
100
80
60
40
20
0
0
4
8
12
16
20
24
Time (Hrs.)

Fig. 2

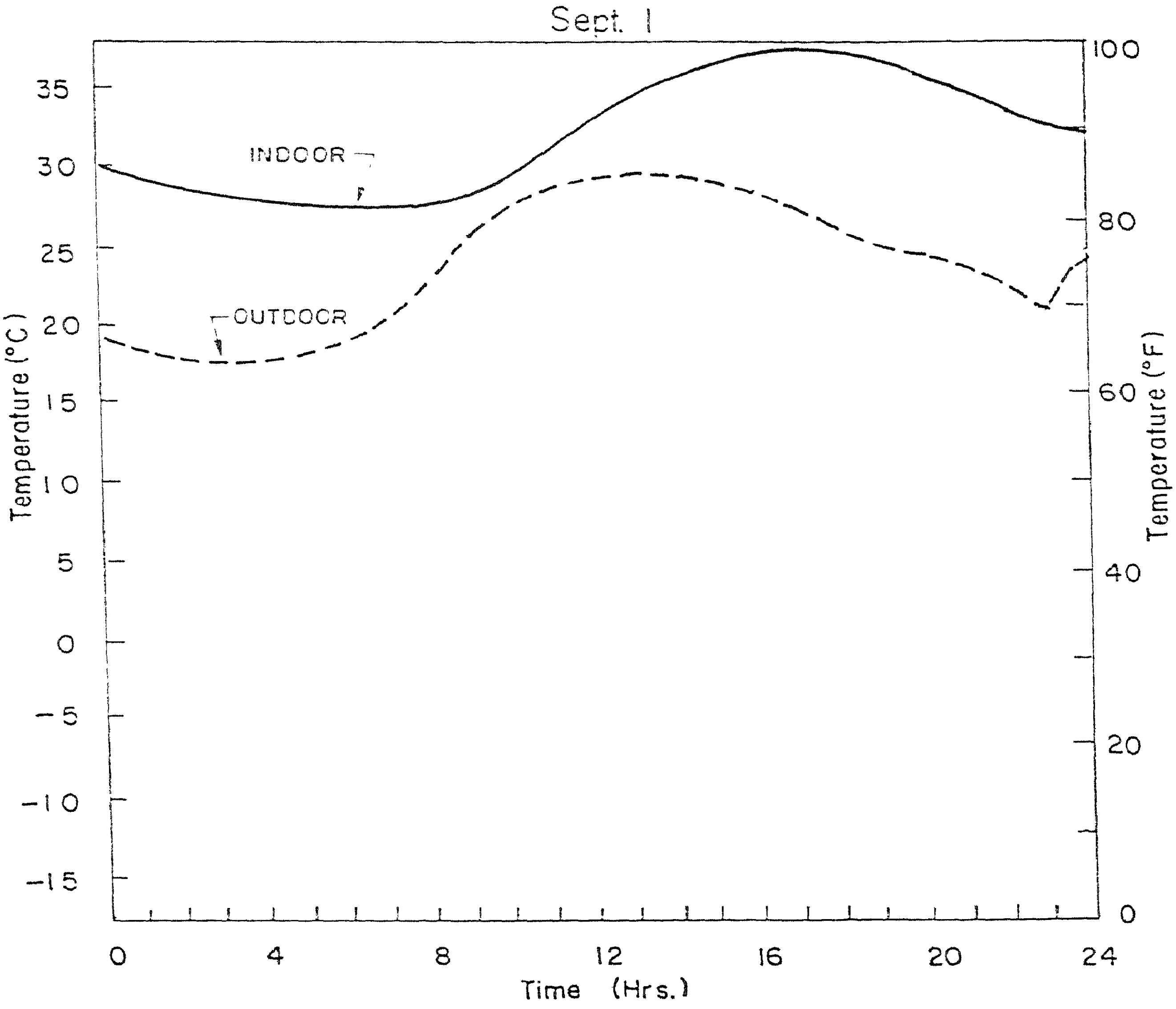

Sept. 1
INDOOR
OUTDOOR
Temperature (°C)
35
30
25
20
15
10
5
0
-5
-10
-15
Temperature (°F)
100
80
60
40
20
0
0
4
8
12
16
20
24
Time (Hrs.)

Fig. 3

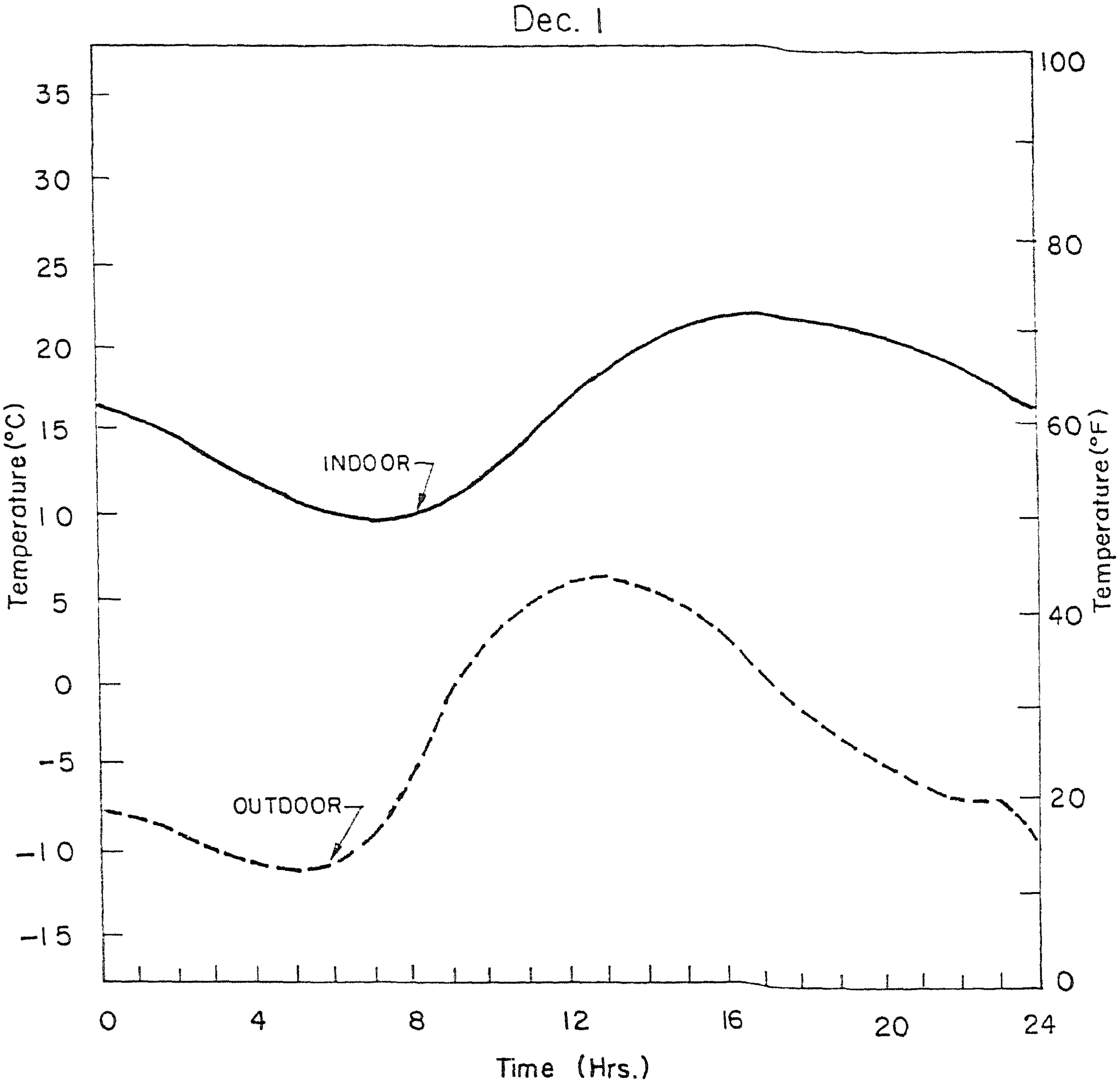

Dec. 1
35
30
25
20
15
10
5
0
-5
-10
-15
Temperature (°C)
100
80
60
40
20
0
Temperature (°F)
INDOOR
OUTDOOR
0
4
8
12
16
20
24
Time (Hrs.)

Fig. 4

Appendix A

PASSIVE SOLAR RETROFIT FOR HEATING OF STAKNA POWER HOUSE

First Progress Report

Ashok Gadgil
Sanjay Rastogi

TATA ENERGY RESEARCH INSTITUTE

NEW DELHI

September 1987

Thermal performance of the Stakna Power House was simulated on a computer for predicting hourly indoor air temperatures in the power house under the following conditions.

(i) The power house building as it stands without any modifications, assuming an infiltration rate of 10 ACH (Air Changes per Hour). This high infiltration rate is based on observations of open single sheeted roof and large openings under the roof awnings on the east and west walls.

(ii) Thermal simulation of the Stakna Power House with various retrofitted measures described below, and assuming a realistic infiltration rate,and generation of internal heat at rates of 20 kW, 10 kW, and 0 kW respectively. These three internal heat generation rates were assumed corresponding to a 1 per cent loss of energy in the generator (core hysterisis and friction losses) at electricity production levels of 2 MW, 1 MW and 0 MW (power station shut-down) respectively.

The measures recommended for passive solar retrofit of the Stakna Power House are listed below. These measures are based on site visit to Stakna Power House and discussions with the responsible officers by Dr. Gadgil in March, 1987. Based on subsequent inspection, measurments and further discussions with engineers and officers dealing with this project, the measures

recommended below may be slightly modified for ease of installation, higher reliability of workmanship and thermal performance, and other such factors.

1) The inside surfaces of the exterior walls facing East, West, and North should be lined with 6" thick insulation of rock-wool (mineral-wool). The insulation should be then surfaced with Asbestos Cement (AC) sheets or Galvanized Iron (GI) sheets.

   On the South wall below the water level, the inside surface should be lined with 6" thick insulation of expanded polystyrene foam (trade name THERMOCOL). The inside surface of the insulation should be again lined with AC or GI sheets.

2. The South wall surface above the water level (between 3486 m and 3495 m above MSL), should have 307m^2 tripple glazed windows made of Poly Vinyl Fluoride (PVF) film of 4 mil thickness. This film is commercially available from Du Pont of USA (trade name is TEDLAR). TERI has identified at least one supplier in India who can provide pre-fabricated windows with aluminium frame tripple glazed with TEDLAR for a reasonably low cost (approximately Rs. 1500/- per square metre of tripple glazed window installed in Leh). The reasons for preferring TEDLAR over other solar glazing material are as follows :

2.1 TEDLAR tripple glazed windows has 20% more transmittance than tripple glazed glass windows and thus provide 20% more heat input.

2.2 TEDLAR has been field tested for at least 10 years in the USA.

2.3 TEDLAR cannot shatter on impact.

2.4 TEDLAR windows are extremely light weight and will have less than 0.5% damage rate in transportation to Leh.

2.5 TEDLAR windows are cheaper than glass windows.

3. The North exterior wall of the building should have a total window area of 24 m^2 which should consist of tripple glazed windows. These may be glass or TEDLAR or a mix of the two types.

4. The turbine floor level should be insulated with 2" thick polyurathene foam slabs which should then be surfaced with floor tiles of appropriate material.

5. A suspended false ceiling should be erected at a height of 3495 m above MSL above the generator floor, and at a height of 3487 m above MSL in the North (office) wing of the building. These two false ceilings should be connected to each other by a continuous vertical strip of false wall that runs the entire East-West length of the building. The construction of the false ceiling should be as follows :

5.1 The bottom-most layer of the false ceiling to be made of appropriate load bearing surface to support the insulation. This material could be corrugated AC or GI sheets or flat AC or GI sheets or any other suitable material.

5.2 A 4 mil of polythene film should be laid on top of the bottom-most supporting layer of the false ceiling.

5.3 A 6" thick batting of mineral-wool insulation should be spread on top of the polythene film.

5.4 A 4 mil film of polythene should be placed on top of the mineral wool insulation.

5.5 The film should be covered with corrugated or flat AC or GI sheets.

The same construction as above should be applied to the vertical false wall that connects the two different levels of false ceilings.

6. Six blowers with a total capacity of 12,000 cfm should be installed at the top of the building (below the false ceiling) to continuously stet air through canvas tubes (diameter 1 m) suspended from the ceiling down to the turbine floor level.

The predicted time versus temperature chart of the hourly indoor temperatures of the Stakna Power House (after the suggested retrofits) is given on the next page for a full year.

5°C

HEATING SEASON COMFORT CHART
TEMPERATURE VS. HOUR OF DAY

HOUR	TEMP= (°F)	22	26	30	34	38	42	46	50	54	58	62	66	70	74	78	82	86	90
1		1	0	0	0	0	0	0	0	6	30	52	55	65	52	56	35	12	1
2		1	0	0	0	0	0	0	1	14	42	49	65	53	54	50	28	8	0
3		0	1	0	0	0	0	0	6	23	49	51	60	51	55	43	23	3	0
4		0	1	0	0	0	0	0	14	44	39	55	52	58	45	43	14	0	0
5		0	1	0	0	0	0	6	23	47	42	52	49	55	42	39	9	0	0
6		0	1	0	0	0	0	10	39	38	46	47	52	49	44	32	7	0	0
7		0	1	0	0	0	2	20	45	32	43	48	54	41	46	31	2	0	0
8		0	1	0	0	0	5	30	37	33	42	42	56	42	48	27	2	0	0
9		0	1	0	0	0	3	28	37	33	40	44	55	43	48	30	3	0	0
10		0	0	1	0	0	0	13	41	35	36	48	48	52	43	40	8	0	0
11		0	0	0	1	0	0	1	30	35	39	44	46	56	46	45	22	0	0
12		0	0	0	0	1	0	0	4	38	31	43	49	47	62	45	38	7	0
13		0	0	0	0	0	1	0	0	7	44	27	51	54	47	61	45	25	3
14		0	0	0	0	0	0	1	0	1	10	46	29	62	57	48	62	32	17
15		0	0	0	0	0	0	0	1	1	1	19	47	49	51	60	58	46	32
16		0	0	0	0	0	0	0	0	1	2	2	42	46	60	61	54	59	38
17		0	0	0	0	0	0	0	0	0	3	2	31	47	60	62	56	61	43
18		0	0	0	0	0	0	0	0	0	3	0	25	58	56	65	56	59	43
19		0	0	0	0	0	0	0	0	0	3	0	33	58	53	70	56	54	38
20		0	0	0	0	0	0	0	0	0	3	3	42	55	65	63	53	51	30
21		0	0	0	0	0	0	0	0	0	3	13	47	58	59	66	51	46	22
22		0	0	0	0	0	0	0	0	1	3	19	59	60	64	61	53	29	16
23		0	0	0	0	0	0	0	0	2	8	41	50	62	61	56	52	23	10
24		0	0	0	0	0	0	0	0	4	12	53	55	62	59	49	50	18	3
TOTAL		2	7	1	1	1	11	109	278	395	574	800	1152	1283	1277	1203	837	533	296 8760

first Day Warm-up

364 day of the yea

Appendix B
Specifications of Retrofit Procedures

1. Insulation Of Turbine Level Floor

1.1 The full turbine floor will be covered with 5 cm (2 inch) thick slabs of polyurethane foam of K (thermal conductivity) value not more than 0.02 W/m-°C.

Recommended Supplier:
Synthetic Foam Limited,
Bhandari House, Third floor,
91, Nehru Place, New Delhi,
Recommended slab size 8 x 4 feet

1.2 Polyurethane slabs will be covered with wood flooring and then with linoleum of design and quality approved by PDD.

1.3 The steel door (1.2m x 2.35m) on the west wall to be lined with 10 cm polystyrene foam slabs (minimum density of 18 kg/cu.m. and K of 0.04 W/m°C), surfaced with 22 gauge GI sheet.

2. Insulation of False Ceilings and Construction of a False Wall

2.1 The existing false ceilings (at height of 3495 m and 3491 m above MSL) will be insulated with 20 cm (8 inch) resin bonded glass wool of density 24 kg/m^3 and K of 0.026 W/m°C. Installation details as shown in Fig. B1.

Recommended Supplier: U.P. Twiga Fibreglass Limited
Twiga House, 3 Community Centre
East of Kailash
New Delhi - 110 065

2.2 A false wall will connect the two false ceilings along the entire east-west length of the building. Its construction will be as shown in Fig. B2.

2.3 Ceiling tiles for the two false ceilings are already in place. The false wall needs to be constructed.

2.4 Plastic films (polythene film, of thickness 4 mil = 0.1 mm) must be laid on the inside surfaces of the false ceilings and the false wall so as to obtain an airtight fit. The film must be laid carefully over the two joints between the false wall and the two false ceilings so that no crack remains for air escape.

3. Dismantling of Part of South Wall, And Closing of Part of the Windows on North Wall.

3.1 All windows (glass and frames) on the south wall to be removed.

3.2 All portions of the south wall made of hollow concrete block between 3487 M and 3495 M to be removed.

3.3 Four equidistant circular holes each to accommodate an exhaust fan diameter 45 cm = 18 inches, to be made above the lintels and just below the false ceiling.

3.4 On the north wall at the Generator floor level, there are eight windows. Glass and steel frame from these windows to be removed, and the resulting openings to be blocked with hollow core concrete bricks, except for a 0.5 sq.m triple paned prefabricated window panel that should be installed in each opening. See Fig. B3. The three ventilator windows on the north wall should also be triple paned.

3.5 Each of the 0.5 sq.m. windows (above) must be triple paned.

3.6 At the 3487 m floor level of the auxiliary bay, there are a total of eight windows facing North. A triple paned window panel of area approximately 1 sq.m. will be installed in place of each existing window. The remaining part of each window opening should be blocked with hollow core bricks.

3.7 The lower half of each triple paned window (in 3.6 above) will be operable. The upper half portions will be fixed.

3.8 All [illegible] four windows on the east wall of the machine hall to be replaced with triple paned TEDLAR windows. Window dimensions to be as shown in Fig. B4.

3.9 Each of the three existing windows on the east wall of the auxiliary bay should be replaced with a triple paned window panel of area 0.5 sq.m. as shown in Fig B4. Remaining glass and steel frames to be removed and excess openings closed with hollow-core concrete blocks. The ventilation port on the east wall should be closed.

3.10 On the west wall of the machine hall there are 5 windows. Of these, the three windows on the south edge of the west wall to be blocked with hollow core concrete blocks. The remaining two windows should be each replaced with 3 units of 1 sq.m. triple paned TEDLAR window panels. Rest of the openings to be blocked with hollow core concrete blocks. See Fig. B5.

3.11 Four window panels, each of 1 sq.m. triple paned TEDLAR, to replace in place of the existing two windows and two ventilators on the west wall of the auxiliary bay.

3.12 Spacing between consecutive panes of triple paned windows should be between 4 cm and 5 cm.

4. Construction of Solar Wall

4.1 At a distance of 30 cm from the exterior face of the south wall, a wall of triple paned TEDLAR window panels will be constructed between 3495m and 3487m, for the full length (36m) of the building. The top, east and west gaps between the TEDLAR panel wall and the south wall to be closed as per the construction shown in Fig B6. for the east-facing gap.

4.2 The TEDLAR window panels will be fixed in I shaped MS channels which are supported by cross-members grouted in the south wall. All airgaps between the adjacent window panels, and between the panels and the I channels should be sealed with liquid polyurethane foam.

5. Construction of Moving Insulation For Rolling Shutters

5.1 An insulation panel of dimensions 6m (width), by 5.5m (height) will be prepared as shown in Fig. B7.

5.2 The polystyrene foam blocks (density 18 kg/cu.m., thickness 10 cm) will be assembled inside a cage made from 18 gauge MS strips. GI sheets 22 gauge will be fixed to the these MS strip cage with self threading screws and washers.

5.3 Guide rails, an electric motor and a winch will be

provided to raise and lower the panel in front of the rolling shutters.

5.4 The bottom edge of the insulation panel will be lined with 2.5 cm (= 1 inch) layer of polythene foam.

Recommended supplier: Profeel Sentinal
Universal Bldg.
2/2, Asaf Ali Road
New Delhi

6. Insulation on Inside Walls

6.1 The inside surfaces of north, east, west walls to be insulated as shown in Fig. B8.

6.2 A grid of 6 mm mild steel bars will be grouted into the wall being insulated. The rods will be spaced 1.25 m. from each other, center to center. The length of each rod projecting outside the wall will be 19 cm. The free end of each rod will have a Mild steel cross tack-welded or fitted to it as shown in Fig. B8.

6.3 GI strips of width 18 cm and thickness 22 gauge will be laid horizontally on the bolts.

6.4 Two rolls of resin bonded glasswool insulation thickness 4 inches will be placed on each GI strip.

6.5 Square GI sheets, 22 gauge and 1.25 m x 1.25 m in size will be fixed with self threading screws and washers to the MS crosses at ends of the bolts as

shown in Fig. 3. In case enough thermatex sheet are available with PDD, they may be used in place of plain GI sheets.

6.6 Polystyrene foam slabs, thickness 15 cm, to be used for insulating all the south wall area below 3487m. Installation as in 6.2 and 6.5 above.

7. Air mixing devices

7.1 Three blowers, each of capacity 4000 CFM, will be installed just below the false ceiling of the machine hall. The blowers will be located directly above the openings in the generator floor.

7.2 Canvas tubes (of diameter = 1 meter) will be used for ducting air from the blowers downwards. Three ducts will extend straight vertically down to the turbine floor level through the already existing openings in the generator floor.

7.3 Four exhaust fans, (diameter 45 cm = 18 inch nominal) will be fixed in the four holes in the south wall provided just below the machine hall ceiling. The fans should have capacity of about 2200 CFM under free flow conditions.

8. Modifications

Minor adjustments to the above can be suggested by the contractor in consultation with TERI.

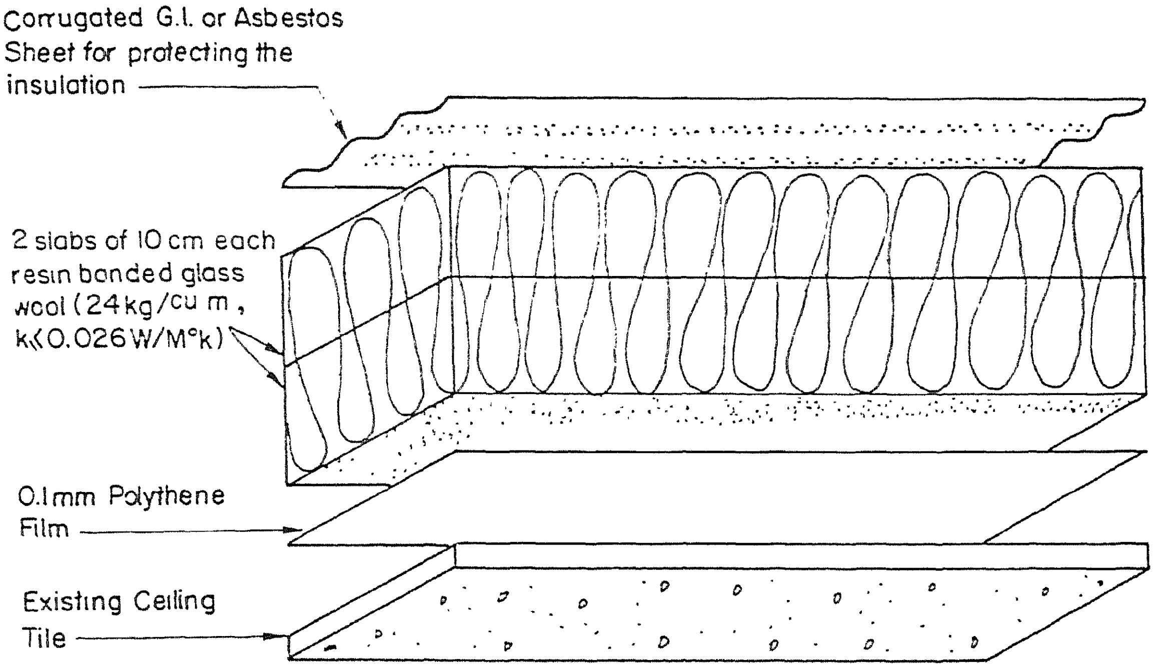

Corrugated G.I. or Asbestos Sheet for protecting the insulation
2 slabs of 10 cm each resin bonded glass wool (24 kg/cu m, k<0.026 W/M°k)
0.1 mm Polythene Film
Existing Ceiling Tile

Fig. B1: Details of Insulation of the Existing False Ceiling

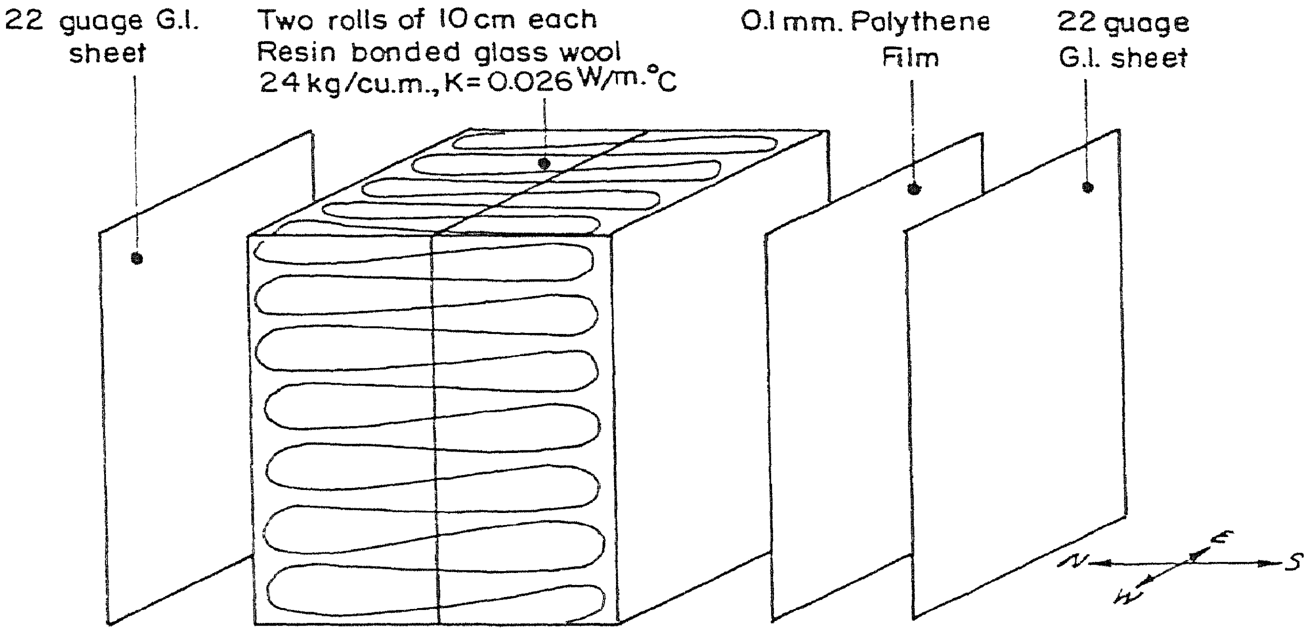
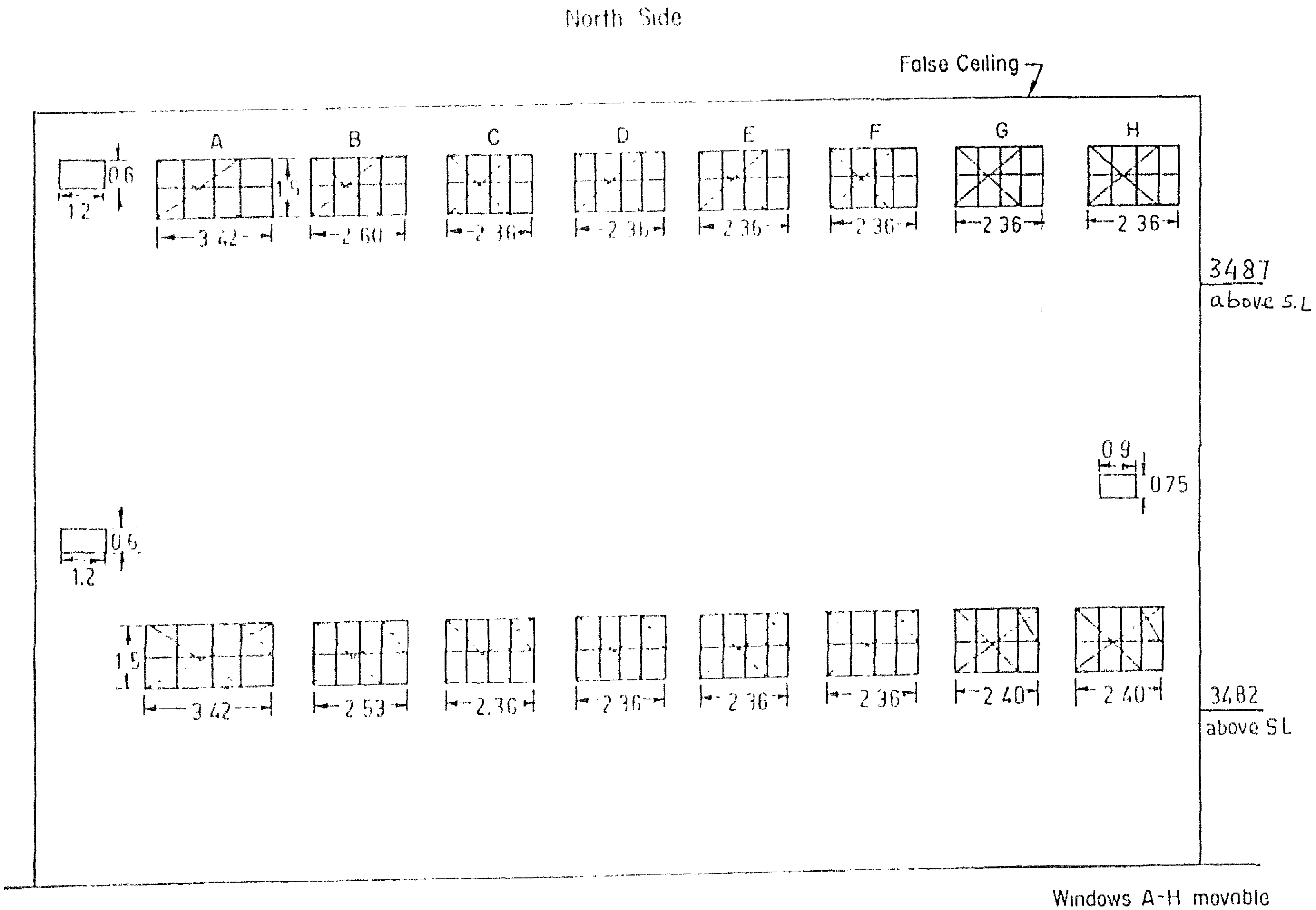

22 guage G.I. sheet
Two rolls of 10 cm each Resin bonded glass wool 24 kg/cu.m., K=0.026 W/m.°C
0.1 mm. Polythene Film
22 guage G.I. sheet
N
S
E
W

Fig. B2: Details of False Wall Construction

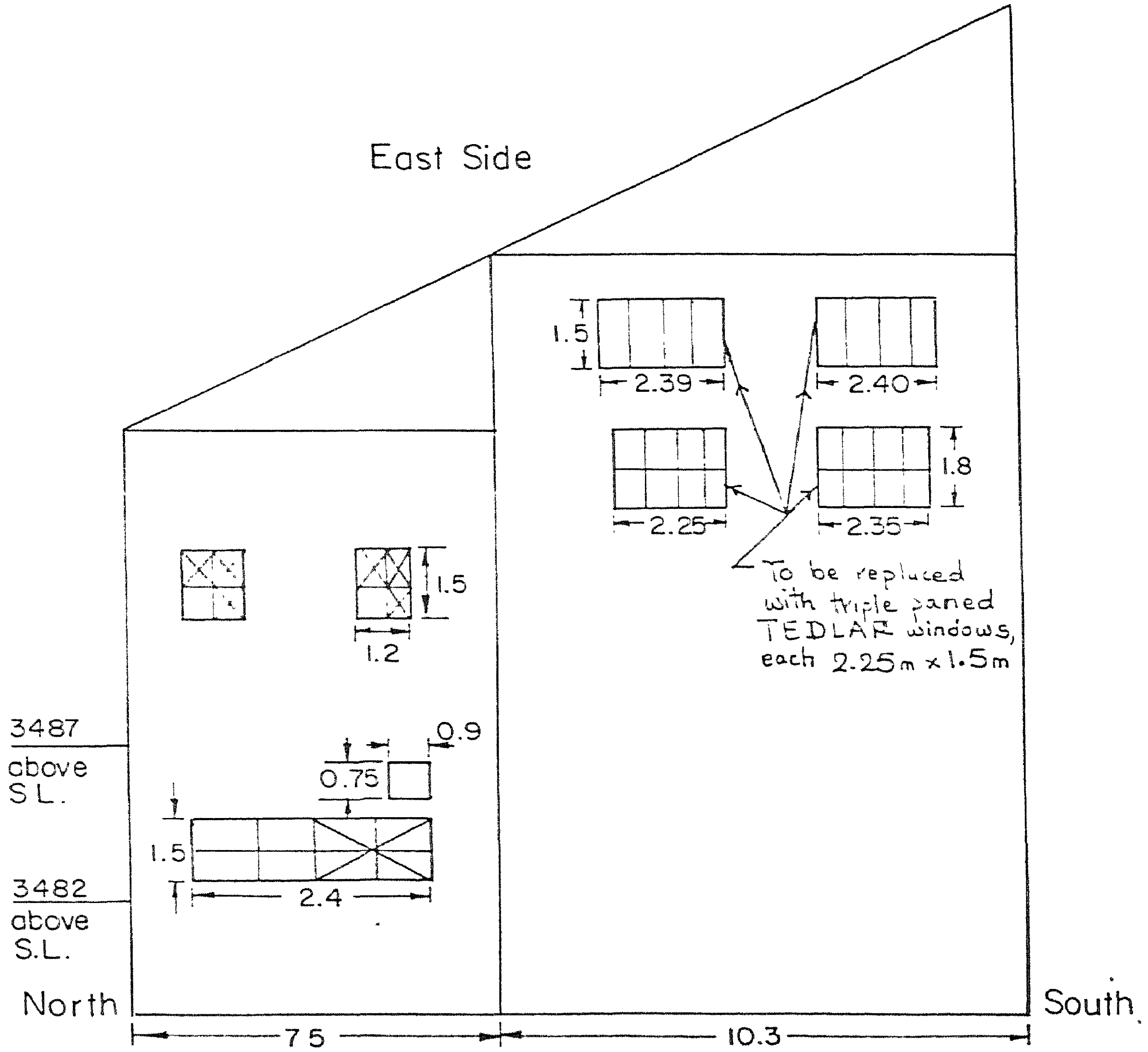


Windows A-H movable
Dimensions in metres

Fig. B3: North Wall Interior View

Crossed areas to be blocked

Clear areas to be triple paned



Dimensions in metres

Fig. B4: East Wall Interior View

Crossed areas to be blocked
Clear areas to be triple paned

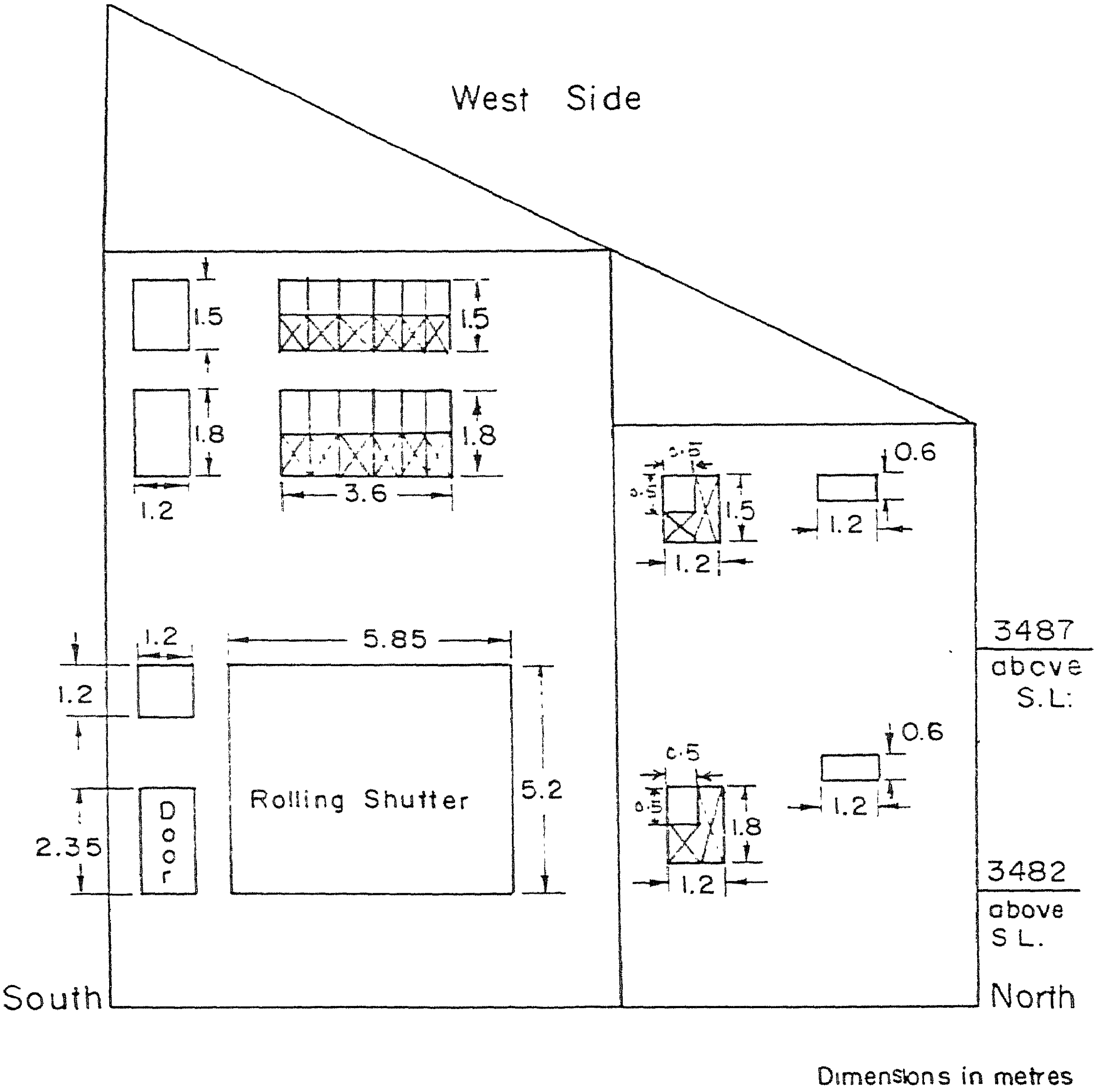
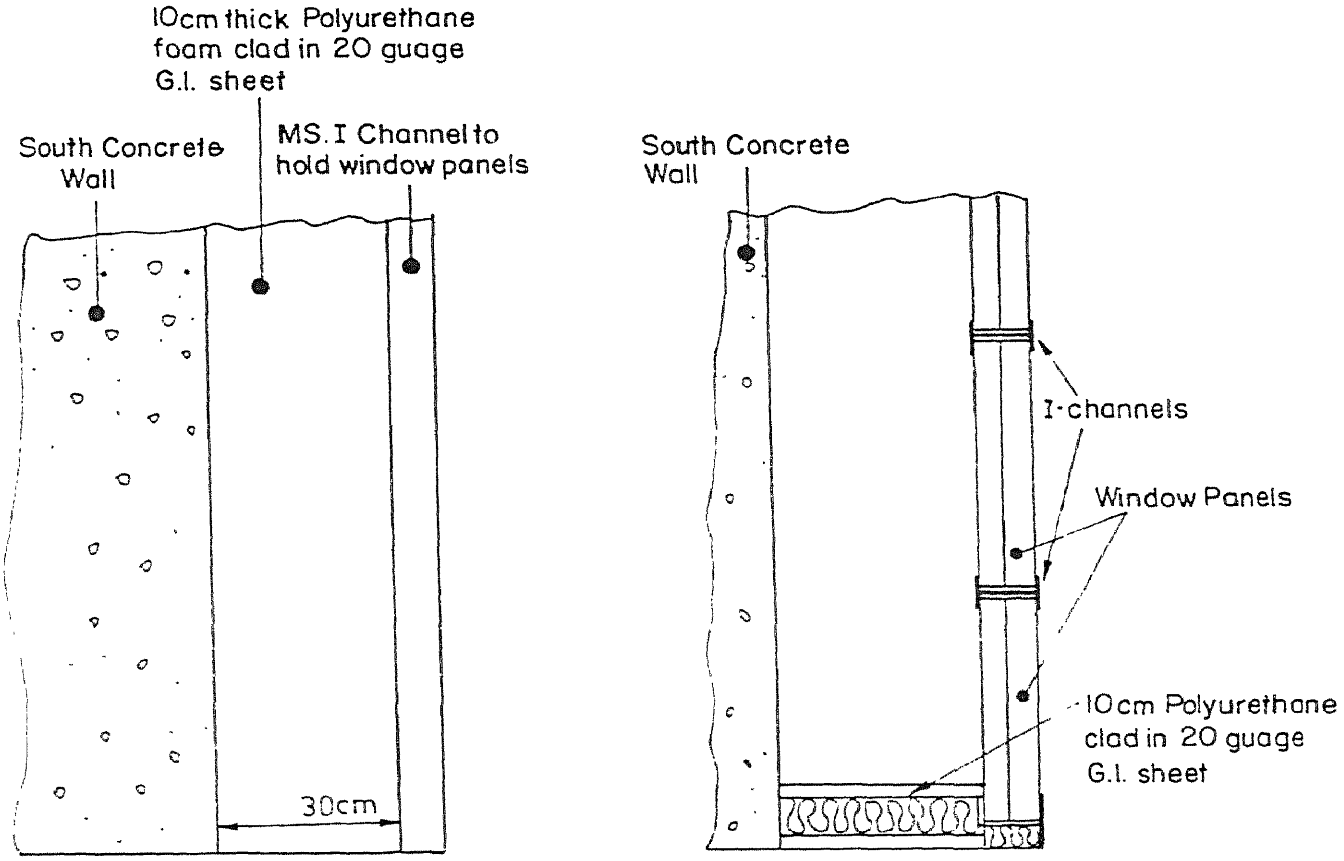


Fig. B5: West Wall Interior View

Crossed areas to be blocked
Clear areas to be triple paned


10cm thick Polyurethane foam clad in 20 guage G.I. sheet
South Concrete Wall
MS. I Channel to hold window panels
30cm
South Concrete Wall
I-channels
Window Panels
10cm Polyurethane clad in 20 guage G.I. sheet

East View

Top View of East Side closure

Fig. B6: Details of Solar Wall Closure on the Eastern Edge

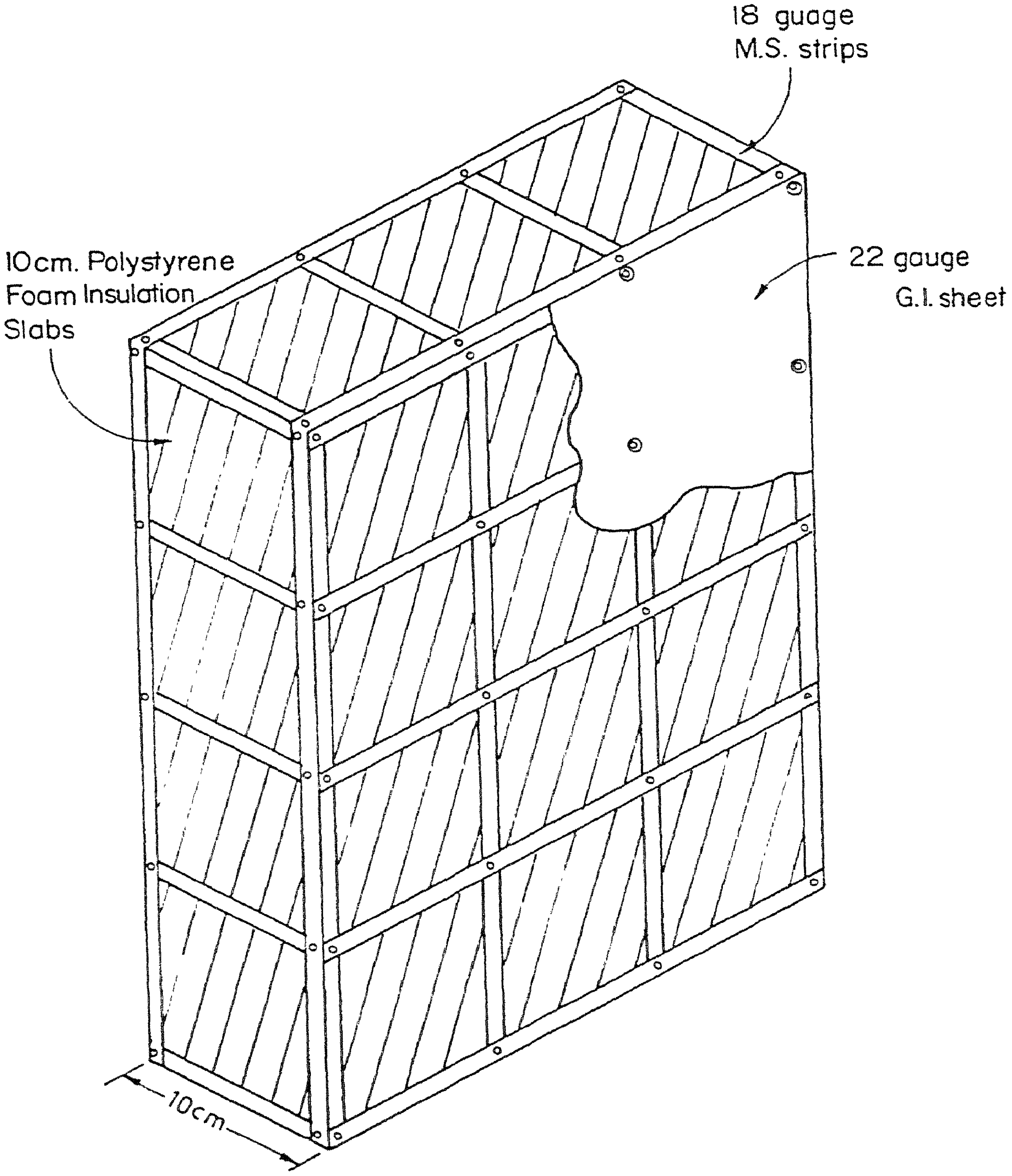


Fig. B7: Insulation Panel for the
Rolling Shutter (not to scale)

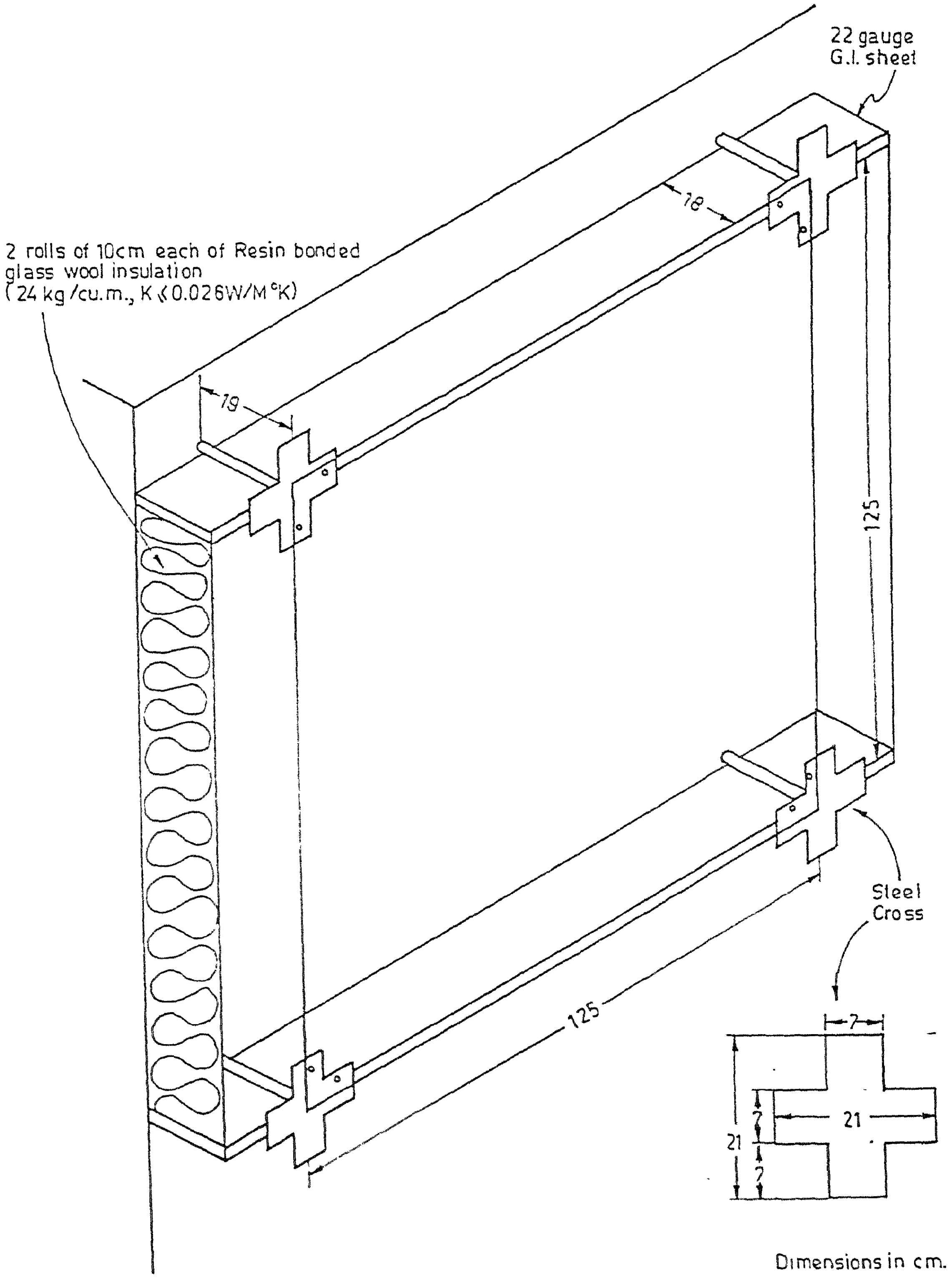

22 gauge G.I. sheet
2 rolls of 10cm each of Resin bonded glass wool insulation (24 kg/cu.m., K ≤ 0.026W/M °K)
18
19
125
125
Steel Cross
7
21
7
21
7
Dimensions in cm.

Fig. B8: Details of Insulation on Inside Walls, N, E and W